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McLennan, John Cunningham
On the radioactivity of
lead and other metals

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PAPERS FROM THE PHYSICAL LABORATORIES

No. 21: ON THE RADIOACTIVITY OF LEAD AND OTHER METALS, BY J. C. McLENNAN AND V. E. POUND

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II.—*On the Radioactivity of Lead and Other Metals.*

By PROFESSOR J. C. MCLENNAN AND V. E. POUND.

(Read May 16, 1907.)

In a paper in the *Phil. Mag.* of September, 1907, Eve states that while investigating the natural ionisation of air confined in vessels made of different metals, he found that 24 ions per cc. were generated per second when the receivers were made of copper, zinc, iron, and tinned iron, while 96 ions per cc. were regularly produced in air per second when the confining vessels were made of lead.

The high conductivity of air contained in lead vessels has been frequently noted by other observers, but from Eve's results it would appear either that lead contains some active impurity from which other metals are entirely free or else that lead possesses an intrinsic radiation very much stronger than that exhibited by other metals.

The view that lead contains an active impurity is supported by a description in the Phys. Zeit. of November, 1906, of some experiments by Elster and Geitel in which they succeeded in extracting from lead oxide small quantities of an active substance which from its characteristics they were inclined to think was radium F. In this paper they state that they were unable to obtain any active emanation from the materials treated, and on this account they suggest that possibly the source of the radium F. can be traced to the presence of radium D in the lead.

Since the decay period for radium D is forty years it would follow. if the high activity of lead is due to the presence of this radium product, that very old lead would exhibit an activity less intense than that which it emitted when freshly mined.

Eve does not appear to have tested many different samples of lead, but if the explanation offered by Elster and Geitel of the high activity of lead be correct, one should expect to find that samples of lead selected at random from different localities would exhibit widely differing degrees of activity.

This difference in the radioactivity of lead obtained from different sources was recently observed by the writers while making some measurements on the conductivity of air contained in metal vessels.

In these experiments the metals examined were made up into cylinders 60 cm. long and 24 cm. in diameter, and from measurements with a sensitive quadrant electrometer on the saturation current through the air which they contained their activities were deduced.

The experiments were conducted in a room free from any artificial contamination from radioactive substances, and in carrying them out the cylinders were first carefully cleaned with glass paper and then thoroughly washed out with hydrochloric acid, water, ammonia, and ethyl alcohol and finally before making the measurements, air filtered through glass and cotton wool was blown through each of them for fifteen or twenty minutes. The results obtained with the different metals examined are contained in Table I.

Table I.

Number.	Material of cylinder Length 60 cm. Diameter 24 cm.	Thickness of sheet in mm.	Average No. of ions per cc. generated per second. = "q"	REMARKS.
1	Lead.	1.85	23	This sample was taken from a sheet of lead which had been used as a lining in a case installed in the University over twenty-eight years ago.
2	Lead.	2.25	160	Commercial English sheet lead obtained from the lead works at Toronto.
3	Lead.	1.45	37	Commercial English sheet lead selected from a different shipment from No. 2.
4	Lead.	1.85	78	This sample was obtained from a sheet rolled from an old pipe which had been used as a drain for 25 or 30 years, and was afterwards melted down.
5	Lead.	1.80	34	Rolled from a pig of lead recently received from the smelter at Trail, B.C., Canada.
6	Lead.	1.80	55	Rolled from English pig lead; Quirk and Bartons.
7	Lead.	1.80	61	Rolled from English pig lead. Cookson's.
8	Zinc.	1.62	15	Commercial sheet zinc.
9	Aluminium.	.41	15	Commercial sheet aluminium.

From this table it will be seen that the values of "q" for aluminum and zinc are somewhat less than those found by Eve for this constant with the same metals. They are, however, in good agreement with H. L. Cooke's corrected value "q"=13.6 given by Eve for air confined in a well cleaned brass vessel.

The values found for "q" in the experiments with lead cylinders, as will be seen from the table, range from 23 to 160 ions per cc. per second. The lowest value, 23, was obtained with the lead which had been in the laboratory between twenty-five and thirty years, and had probably been a very much longer time away from the mine. With the cylinder No. 4, which was made from an old drain pipe, the value of "q" was found to be 78, a somewhat higher value than that obtained with No. 1. Although both of these cylinders were made of comparatively old lead it is highly probable that No. 4, from the nature of its use had become contaminated with some active substance. It may possibly too have possessed a higher activity than No. 1 when originally mined.

With cylinder No. 5 the value obtained for "q" was 34 ions per cc. per second. This lead, we have reason to believe, was mined not more than two or three years ago, and under the circumstances might have been expected to show a much higher activity. Its activity, however, was practically the same as that of No. 3, which was selected at random from a commercial sheet of lead which probably had been on the market for some years.

Cylinders No. 6 and No. 7 possessed a moderate activity compared with the others of the same metal. The number of ions per cc. generated in air per second with them being 55 and 61 respectively.

With cylinder No. 2, the greatest ionization was obtained, the value of "q" in this case being 160 ions per cc. per second.

This cylinder was treated precisely the same as the others, but on account of its high activity special measurements were made with it in order to investigate more fully the character of the radiation which it emitted.

Measurements on the radiation from this cylinder showed it to be in great measure an easily absorbed one. When aluminum linings 0.73 mm. thick were inserted in cylinders No. 1 and No. 2, and No. 3 and measurements made on their saturation currents the values of "q" were found to be 12.0, 13.3, and 14.4, respectively. These numbers it will be seen, are slightly lower than those found for aluminium alone, which is exactly as one would expect owing to the absorption of the penetrating rays from the earth by the lead. The value for "q" 13.3 found for No. 2 is slightly greater than that "q"=12 given by No. 1, although this lead cylinder was 2.25 mm. thick, while No. 1 was only 1.85. This would seem to indicate the existence of a slight penetrating type of radiation issuing from No. 2 which was absent from cylinder No. 1.

A second series of measurements was made with cylinder No. 2 to investigate the distribution of the substance which was the cause of its high activity. Readings were taken on the saturation current first with the lead cylinder entirely unscreened, then with the one half of the cylindrical surface screened internally with aluminium 0.73 mm. thick, and finally with the whole of the inner cylindrical surface covered with the aluminium.

The values are given in Table II.

Table II.

Experiment Number.	Cylinder No. 2.	Ionization (Arbitrary Scale).	Decrease in Ionization (Arbitrary Scale).
1	Completely unscreened..	54.6	22.2
2	One-half inner cylindrical surface screened..........	32.4	22.57
3	All inner cylindrical surface screened..................	9.87	

and from them it will be seen that the decrease in conductivity was the same for each half of the cylindrical surface. This goes to show that the radioactive impurity in the lead was uniformly distributed over its surface. It was also very probably distributed in a uniform manner throughout the mass of the cylinder as repeated scourings with glass paper failed to remove it. In this connection it is of interest to note that during the last six months, measurements have been repeatedly made on the conductivity of air confined in this cylinder, but during that period no indication of a falling off in the intensity of the radiation from it has been observed.

From the foregoing results it is abundantly evident that the high activity of lead which has from time to time been recorded by a number of observers can not be ascribed to any intrinsic property of the metal, but must be connected with the existence in it, in amounts varying with different specimens, of some foreign body of considerable activity.

The low value obtained for the conductivity of air enclosed in cylinder No. 1 suggested the possibility that the difference between the reading for this cylinder and that obtained with the aluminium cylinder No. 9 was due entirely to a difference in the secondary rays excited in the two metals by the penetrating radiation from the earth. With the object of clearing up this point observations are still being made with the cylinders, and from results obtained already, it would seem that, apart from active impurities, differences in the secondary radiation will suffice to explain the differences in conductivity obtained with air confined in vessels made of different metals.

UNIVERSITY OF TORONTO STUDIES.

The "Papers from the Physical Laboratories," to be issued as a special series of University of Toronto Studies, date from the year 1900. Nos. 1-17 were published by the Physical Department in a very limited edition and are no longer in print. For the sake of a complete record the numbering of the Papers, as forming a series of University of Toronto Studies, is made continuous with the earlier series and commences with number 18. The earlier numbers, except those to which a price is attached, are not now available either for sale or gift.

No. 1: Electric Screening in Vacuum Tubes, by J. C. McLennan.
Trans. Roy. Soc. of Canada, second series, Vol. VI, Sec. III (1900).

No. 2: Electrical Conductivity in Gases traversed by Cathode Rays, by J. C. McLennan.
(*a*) Phil. Trans., A. Vol. 195 (1900), pp. 49-77.
(*b*) Zeitschrift f. Physik. Chemie XXXVII, 5 (1901).

No. 3: On a kind of Radioactivity imparted to certain Salts by Cathode Rays, by J. C. McLennan.
(*a*) Phys. Zeit. Vol. 2, No. 49, pp. 704-706 1901).
(*b*) Phil. Mag., Feb. 1902.

No. 4: On excited Radioactivity, by R. M. Stewart.
Trans. Roy. Soc. of Canada, second series, Vol. VIII, Sec. III (1902).

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(*a*) Phys. Zeit., 4, No. 10, pp 295-298 (1903).
(*b*) Phil. Mag., April 1903.
(*c*) Physical Review, Vol. XVI, No. 4 (1903).
(*d*) University of Toronto Studies, Physical Science Series, No. 1.

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Proc. of Select Standing Committee on Agriculture and Colonization of the House of Commons, Canada, March 29, 1904.

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